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Evaluation of Combined Weed Control Practices on Weed Dynamics, Yield and Economic Return in Common Bean (Phaseolus vulgaris L.) at Wolaita Sodo, Southern Ethiopia

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Abstract
The field experiment was conducted in Wolaita Zone, Southern Ethiopia, to evaluate different weed management practices on weed dynamics, yield and economic return in common bean in 2014. The experiment comprised of fifteen treatments which included two herbicides (s-metolachlor and pendimethalin) applied as pre-emergence alone and in different combinations, hand weeding and hoeing, weedy check all with and without mulching and weed free check laid out in randomized block design with three replications. The application of pendimethalin 1.0 kg ha^{-1}+ mulching at 2 weeks after crop emergence (WAE) resulted in significant decrease in total weed density over weedy. Weed dry weight varied in response to weed significantly management practices at 2 WAE. However, at 12 WAE this has no significant difference with pendimethalin 1.0 kg ha^{-1}+ hand weeding and hoeing 5 WAE, s-metolachlor 0.75 kg ha^{-1}+ pendimethalin 0.75 kg ha^{-1}+ mulching and hand weeding and hoeing at 2 and 5 WAE. At 12 WAE, the highest weed control efficiency (99.8%) was obtained with hand weeding and hoeing at 2 and 5 WAE which is statistically at parity with pendimethalin 1.00 kg/ha+ hand weeding and hoeing 5 WAE (99.4%. Weed infestation throughout the growing period suppressed the plant height by about 29.6 to 95.3% compared to other treatments. The highest number of pods per plant was recorded under complete weed free and it was statistically in parity with pendimethalin at 1.0 kg ha^{-1}+ hand weeding and hoeing 5 WAE. Weedy check resulted in significant decrease in number of pods per plant which varied between 28.6 and 54.4% over other treatments. The highest number of seeds/pod was also obtained with complete weed free plots but in addition to pendimethalin at 1.0 kg ha^{-1}+ hand weeding and hoeing 5 WAE, Weight of hundred seeds was maximum with complete weed free which was statistically in parity with the application of pendimethalin at 1.0 kg ha-1 + hand weeding and hoeing at 5 WAE and two hand weeding and hoeing 2 and 5 weeks after crop emergence (WAE) treatments. Highest grain yield (1982 kg ha^{-1}) and net returns (ETB 17362 ha^{-1}) was obtained with the application of pendimethalin 1.0 kg ha^{-1} + hand weeding and hoeing 5 weeks after crop emergence. Generally, it could be concluded that pendimethalin 1.0 kg ha-1 combined with one hand weeding and hoeing at 5 WAE was the most appropriate method for effective weed management and profitable production of common bean.
Keywords: Herbicides combination, mulch, pendimethalin, pre-emergence, s-metolachlor, yield, economic feasibility
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1. INTRODUCTION

1.1 Background and Justification

Common bean (*Phaseolus vulgaris* L.) is one of the most produced grain legumes word wide. It is the second most important grain legume cultivated as cash crop in Ethiopia (CSA, 2013). The estimated production area and yield of common bean in Ethiopia in 2012/2013 cropping season were 366,876.94 hectares and 4,630,08.49 tons, respectively, with average grain yield of 1262 kg ha^{-1}(CSA, 2013).In southern parts of the country, it is widely distributed and grown by farmers for various uses (Tenaw, 1990)Common bean occupies about 7.6% of the total grain crop area and covers 5.51% of the regional total grain production (CSA, 2010).The major haricot bean producing area in the Southern Region includes Gamo Goffa, Sidamo and Wolaita (Gedno, 1990). Yield of legumes in farmer's field is usually less than 0.65 t ha-1against the potential yield of 1.2 t ha-1suggesting a large yield gap (CACC, 2002). Low yield potential of legumes has made them less competitive with cereals and other high value crops. The average national productivity of haricot bean is 0.72 t ha^{-1}(CACC, 2002) and its regional productivity is 0.81 t ha^{-1}.

Even though common bean is widely grown in Ethiopia, the national average yield (1.27 t^{-1}) is far less than the attainable yield (2.5-3.6 t ha^{-1}) under good management conditions (CSA, 2012). Low yield of common bean in Ethiopia is attributed to several production constraints which include lack of improved varieties for the different agro-ecological zones, poor cultural practices, such as untimely and inappropriate field operations, weed infestation, low soil fertility, water stress, diseases and insect pests (Imru, 1985).

Weeds infestation is one of the main constraints in crop production in Ethiopia, especially during the rainy season. Weeds population reduced common bean seed yield and caused difficulties in the harvesting operation in cultivated areas (Amini et al., 2013). Weeds increased the bean drying time in the field, resulting in yield losses due to shattering (Waters and Morishita, 2001).Grain yield showed a declining trend with increase in the time of weed infestation. Zimdal*et al.* (2010) reported that the decrease of yield is 70% that results from the interference of weeds in bean. Red bean belongs to plants sensitive to weed competition. Its competition not only reduces the yield but also the bean quality, affecting seed size, plant height and pod length.

Farmers in the study area are aware of weed problem in their fields but often they cannot cope-up with heavy weed infestation during the peak-period of agricultural activities because of labour shortage. Hence, most of their fields are weeded late or left unweeded. Such ineffective weed management is considered as the main factor for low average yield of common bean resulting in average annual yield loss of 36% to as high as 94% (Stroud, 1989). In addition to this, research result indicated that weed interference in common beans can result in yield losses up to 85% (Dawit et al., 2011; Pynenburg et al., 2011; Mengesha et al., 2012). So, increasing productivity of common bean is one of the ways to raise the living standards of the rural population and to ensure food security and poverty alleviation.

Hand weeding is the predominant weed control practice on smallholder farms (Vissoh et al., 2004). Efficient control of weeds and lower dry matter production of weeds and control of later weeds through hand weeding provide weed free and congenial environment to the crop (Pisal et al., 2013). On the other hand, research has shown that use of herbicides produce greater yield at less cost than the typical practice of hand weeding. Chemical control is a better alternative to manual weeding because it is easier, cheaper, faster and gives better weed control (Chikoye et al., 2004). Most herbicides can control certain weed species at doses well below the recommended dose while other weed species require higher doses and yet others are not controlled even at the recommended dose. Therefore, appropriate herbicide mixtures can be utilized for broad spectrum weed control. Mulching has a smothering effect on weeds by restricting light to the green portion or portion above the soil. Straw, saw dust, plant residues and stubbles are used as mulching material. Moreover, mulching along with weed management practices may bring some promising effect on weed control and crop yield. Therefore, optimizing herbicide performance should be considered as one element in an integrated weed management strategy by integrating two or more direct weeding methods in combination than any single method in alleviating the build-up of weeds in a crop (Lamichhane et al., 2017).

Several research publications (e.g. Sanbagavalli., et al., 2016; Meena*et al*., 2013; Singh et al., 2001; Dungarwal et al., 2003) have proved that integration of herbicides with hand weeding is the most effective and economical method of weed management. Thus, good weed control usually involves a combination of the available methods plus timeliness and good cultural practices (Abu-Hamdeh, 2003). Therefore, the objectives of the study were: to determine the effects of weed control practices on weed dynamics, grain yield and economic return in common bean.

3. MATERIAL AND METHODS

3.1 Description of Experimental Site

The experiment was conducted at the Wolaita Sodo Agricultural, Technical and Vocational Education and Training (ATVET) College farm (6°34'N latitude; 37°43'E longitude; altitude of 1954 m.a.s.l), Southern in the main cropping season of 2014. The site has a bimodal rainfall distribution pattern with average annual rainfall of 1572.3 mm and the average minimum and maximum air temperatures of 14.9 °C and 23.1 °C, respectively (National Meteorology Agency, Wolaita Sodo branch 2014). The soil of the experimental field was sandy clay loam with soil pH of 5.5, has low phosphorus and organic matter content (Wolaita Zone Soil Laboratory, 2014).

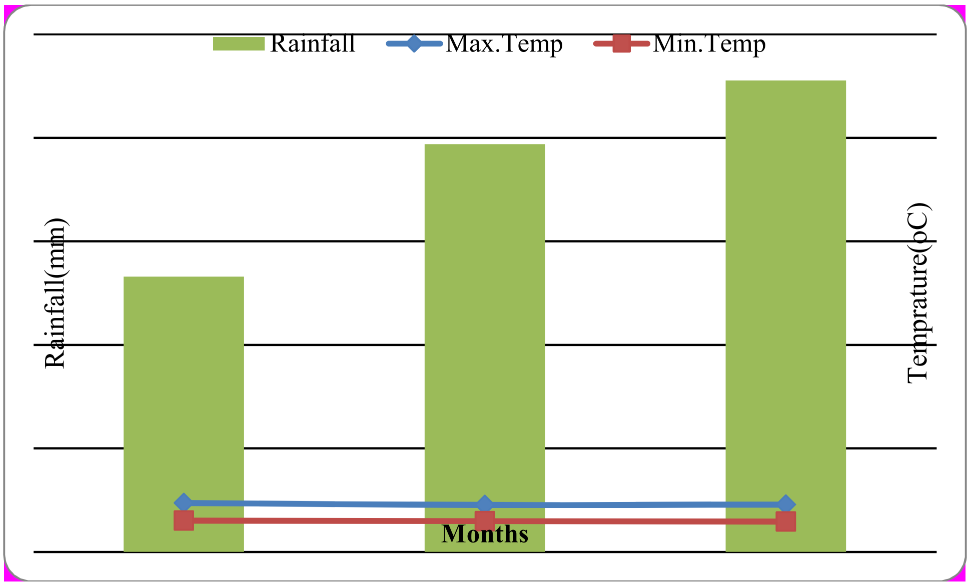

Fig.1 Monthly total rainfall (mm) and maximum and minimum air temperatures (°C) at Wolaita Sodo in 2014
Source: Wolaita Sodo Meteorological Station

3.2 Experimental Materials

Widely grown common bean variety 'Red Wolaita' was used for the experiment. It has an intermediate bush with prostrate stem with the ability to climb (growth habit III b). It has a yield potential of 1.9-2.1 tons ha^{-1}. The mulching material (grass) was cut and allowed to dry. Before applying, the mulch material was chopped into approximately 30 to 45 cm pieces. S-metolachlor and pendimethalin were used for the experiment. Their common, trade and chemical name are presented in Table 1.

Table 1 Description of herbicides used for the experiments

Common name	Trade name	Chemical name
S-metolachlor	Dual Gold 960EC	[2-chloro-6`-ethyl-N-(2-methoxy^{-1}-methylethyl) acet-o- toluidide]
Pendimethalin	Stomp 30 EC	[N-(1-ethylpropyl)-2, 6-dinitro-3, 4-xylidine]

3.3 Treatments and Experimental Design

The experiment consists of 15 treatments viz. 1) S–metolachlor 1.00 kg/ha + Mulching, 2) Pendimethalin 1.00 kg/ha + Mulching, 3) S-metolachlor 1.00 kg /ha + Hand weeding and hoeing 5 week after emergence (WAE), 4) Pendimethalin 1.00 kg /ha + Hand weeding and hoeing 5 WAE, 5) S-Metolachlor 0.75 kg/ha + Pendimethalin 0.75 kg/ha, 6) S-Metolachlor 0.75 kg/ha + Pendimethalin 0.75 kg/ha + Mulching, 7) S-Metolachlor 0.50 kg/ha + Pendimethalin 0.75 kg/ha, 8) S-Metolachlor 0.50 kg/ha + Pendimethalin 0.75 kg/ha + Mulching, 9) S-Metolachlor 0.75 kg/ha + Pendimethalin 0.50 kg/ha, 10) S-Metolachlor 0.75 kg/ha + Pendimethalin 0.50 kg/ha + Mulching, 11) Hand weeding and hoeing 2 and 5 WAE, 12) Hand weeding and hoeing 2 WAE + Mulching, 13) Weed Free, 14) Weedy Check; and 15) Weedy Check + Mulching.

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The size of the experimental plot was 3.0 m x 2.4 m (7.2 m^{-2}). The path width was 0.5 m between plots and 1.0 m between blocks. There were six rows spaced 40 cm and 30 plants per row each spaced 10 cm rows. The outer most two rows and two plants from each end of the rows were considered as border. Thus, the net plot size was 2.6 m x 1.6 m (4.16 m2).

3.4 Crop Management

The experimental field was ploughed twice by oxen to get fine seed bed. Each plot was levelled manually after the field layout was made. Planting was done at a specified inter and intra row spacing on June 1st 2014. Two common bean seeds were placed per hill and later thinned to one plant after emergence. The recommended amount of nutrient (18 kg N+ 46 kg P_2O_5 /ha) was applied through 100 kg Di-Ammonium Phosphate (18% N; 46% P_2O_5) in furrows at the time of sowing. The herbicides s-metolachlor and pendimethalin were applied as pre emergence onto the soil one day after planting with Knapsack sprayer using Flat fan nozzle in specified plots. The spray volume water as a carrier was 500 L/ha. In treatments that included combined use of herbicide and mulching, the mulching was done immediately after spray. Mulch material was spread uniformly on soil surface with a thickness of approximately 10-15 cm layer and hand pulling was made in weed free plot periodically. All the other practices were followed as per the recommendation to raise the crop. Harvesting of the crop was done on August 29, 2014

3.5 Data Collected

3.5.1 Parameters for weeds

Weed community: Data on weed flora present in the experimental field were recorded during the experimental period (June, 2014). The weeds that were easy to identify were recorded in the field. Those species which could not be identified in the field were brought to the laboratory and were identified using the weed identification guide.

Weed density: The weed density was recorded with the use of quadrat (0. 25 m x 0. 25 m) thrown randomly at two places in each plot. Weeds with their root system falling within each quadrat were counted and categorized as broadleaved, grass and sedges and converted in to density per m^{-2} before hand weeding and 15 days before crop harvest which was designated as at harvest. After recording the data on density, plot wise weeds within each quadrat were cut near the soil surface and placed into paper bags. The weed species found within the sample quadrat were identified, counted and expressed in m^{-2}.

Weed dry weight: The weeds falling within the quadrat were cut near the soil surface immediately after taking observation on weed count and placed into paper bags treatment wise. The samples were sun dried for 3-4 days and thereafter were placed in an oven at 65°C temperatures till constant weight and subsequently their dry weight was measured. The dry weight was expressed in g m^{-2} and data on weed density and dry matter were subjected to transformation (m^{-2}) before analysis.

Weed control efficiency (WCE): Indicates the comparative magnitude of reduction in weed dry matter by different weed control treatment. It was calculated as;

$$WCE = \frac{(WDC - WDT)}{WDC} \times 100$$

Where, WDC=Weed dry weight in weedy check; WDT= Weed dry weight in a particular treatment.

3.5.2 Parameters for crop

To determine the effect of weed management strategies on the yield and yield components of Common bean during the study the following parameters such as number of pods per plant, number of seed per pod, aboveground dry biomass, 100- seed weight (adjusted at 10.5% grain moisture content.), and grain yield were recorded within the net plot in the experiment.

The yield was adjusted at 10.5% moisture content by using the formula:

$$\text{Adjusted yield (kg)} = \text{Recorded seed weight} \times \frac{100-M}{100-D}$$

Where, M= Measured moisture content in grain, D = Designated moisture content

3.6 Economic analysis

Relative net return: It was calculated by taking into account the additional input cost involved and the gross returns obtained from different weed control treatments.

The price of common bean seeds (Birr/kg) was obtained from the local market and the total price of the commodity obtained from each treatment was computed on hectare basis. Input costs like herbicides and labour were converted into hectare basis according to their rates used. Thus, the total cost that varied across the treatments included the cost of harvesting, hand weeding & hoeing, spraying, mulching and application, threshing, packing, winnowing and transportation which varied in proportion to the yield under a particular treatment (CIMMYT, 1988).

Gross benefit: Assuming that the farmer will not get the same yield as the researcher the yield was adjusted downward by 10% before calculating the gross return. To find out the gross return, the price of common bean grain prevailing in the local market at the time of harvest was taken into account (Birr 12 kg^{-1}).

Net benefit: The net benefit based on the total variable cost was determined by subtracting the respective cost involved from the gross benefit. This was done to have an idea of how much benefit can be obtained based on variable input cost. However, a farmer may be concerned with the net benefit that he/she expects to get with the increase in yield due to adaptation of a technology.

3.7 Data Analysis

All data were subjected to analysis of variance (ANOVA) for randomized complete block design as per Gomez and Gomez (1984) and analysed using GenStat version 12.1(GenStat, 2012). Difference between means was compared using the least significant difference (LSD) test at 5 percent level of significance.

4. RESULTS AND DISCUSSION

4.1 Weed Component

4.1.1 Weed community: The crop was infested with nine major weeds species belonging to five plant families (Table 2). The major weeds in the experimental field during the crop growing period were broadleaved and grasses.

Table 2 Major weed species found in the experimental field of common bean at Wolaita Sodo in 2014

Weed type	Common name	Scientific name	Family name
Grass	Bermuda grass	Cynodondactylon Pers.	Poaceae
	Goose grass	Eleusineindica (L.) Gaertn.	Poaceae
	Wild oat	Avenafatua L.	Poaceae
Broadleaved	Mexican marigold	Tagetesminuta L.	Asteraceae
	Green pigweed	Amarathushybridus L.	Amaranthaceae
	Jimson weed	Daturastramonium L.	Solanaceae
	Black jack	Bidenspilosa L.	Asteraceae
	Cocklebur	Xanthium strumarium L.	Asteraceae
Sedge	Nut grass	Cyperusrotundus L.	Cyperaceae

4.2 Weed density and dry weight

The weed density and dry weight were found to have been significantly (P<0.01) affected by the weed management practices. The lowest weed density (82.9 No/m^{-2}) was recorded with the application of pendimethalin 1.0 kg ha^{-1}+ mulching at 2 WAE as compared to PEN 1.0 kg ha^{-1} + hand weeding and hoeing at 12 WAE (Table 3). Sajid*et al.* (2012) reported the highest weeds density in weedy check; while, the lowest weeds density was noticed with application of s-metolachlor in pea (*Pisumsativum*L.). A minimum weed dry weight was registered in plots receiving two hand weeding 2 and 5 WAE (1.0 g m^{-2}) but it had no significant difference with weed dry weight obtained with the application of pendimethalin 1.0 kg ha^{-1} + hand weeding and hoeing 5 WAE (1.7 g m^{-2}) and s-metolachlor 0.75 kg ha^{-1} + pendimethalin 0.75 kg ha^{-1} + mulching at 12 WAE. Mohammed et al. (2014) reported that pendimetalin + one hand weeding recorded the minimum weed dry weight at different crop development stages. The results depicted that the application of pendimethalin 1.0 kg ha^{-1} combined with one hand weeding provided prolonged weed control, and significant reduction in weed dry weight at harvest. Kolhe (2001) also indicated that dry matter of weeds was significantly reduced due to application of pendimethalin, s-metolachlor, oxyfluorfen either alone or in combination with hand weeding at 35 DAP compared to weedy check in onion. Application of s- metolachlor 1.0 kg ha^{-1} supplemented either with mulching or hand weeding 5 WAE did not show appreciable reduction in weed dry weight compared to most of the treatments which could be due to its moderate persistence in the soil environment. Moreover, soils with significant soil water content may show more rapid breakdown (Kamrin, 1997) thus proving less effective. Sharma *et al.* (2004) found 1.5 kg ha^{-1} of s-metolachlor to be effective for the control of weeds in common bean. But the selectivity and weed control greatly depend upon soil type, atmosphere temperature and rainfall. On the other hand, pendimethalin is absorbed by plant roots and shoots and inhibits cell division and cell elongation (Kamrin, 1997). This inhibition of weeds plants might be responsible for the reduced density and dry weight of weeds.

Table 3 Effect of different weed management practices on weed density and weed dry weight in common bean

Treatments	Weed density (No/m^{-2})		Weed dry weight (g m^{-2})	
	2 WAE	12 WAE	2 WAE	12 WAE
MET 1.00 kg^{-1}+ Mulching	12.6^{a}(158.2)	9.8^{cde} (96.3)	4.1^{abcd} (16.6)	8.3^{cde} (68.4)
PEN 1.00 kg^{-1}+ Mulching	9.1^{b}(82.9)	6.7^{fg} (44.5)	3.0^{g} (8.5)	6.8^{ef} (45.4)
MET 1.00 kg^{-1}+ HWH 5 WAE	11.9^{ab}(142.1)	10.7^{cde}(114.4)	4.4^{abc} (18.6)	10.7^{c} (114.0)
PEN 1.00 kg^{-1} + HWH 5 WAE	10.0^{ab}(99.6)	1.6^{h} (2.0)	3.4^{efg} (11.1)	1.7^{gh} (2.4)
MET 0.75 kg-1 + PEN 0.75 kg-1	13.1^{ab}(171.3)	11.7^{cd}(136.1)	3.6^{cdefg} (12.5)	6.3^{ef} (39.3)
MET 0.75 kg-1 + PEN 0.75 kg-1 + Mulching	9.8^{ab}(96.7)	8.2^{ef} (67.5)	3.2^{fg} (9.8)	3.1^{gh} (9.3)
MET 0.50 kg-1 + PEN 0.75 kg-1	12.1^{ab}(146.9)	8.9^{def} (78.1)	3.9^{bcdef} (14.8)	10.1^{cd} (101.5)
MET 0.50 kg-1 + PEN 0.75 kg-1 + Mulching	10.2^{ab}(104)	8.0^{ef} (64.2)	3.7^{cdef} (13.2)	8.0^{cde} (64.0)
MET 0.75 kg-1 + PEN 0.50 kg-1	13.4^{a}(180.4)	12.3^{c}(151.4)	3.5^{defg} (11.8)	9.9^{cd} (97.7)
MET 0.75 kg-1 + PEN 0.50 kg-1 + Mulching	9.5^{ab}(89.8)	6.1^{fg} (36.3)	3.2^{fg} (9.8)	7.4^{de} (54.3)
HWH at 2 and 5 WAE	11.8^{ab}(139.7)	4.8^{g} (22.57)	4.6^{ab}(20.7)	1.0^{h} (1.0)
HWH at 2 WAE + Mulching	11.4^{ab}(129.5)	7.8^{ef} (60.2)	4.0^{bcde} (15.5)	4.3^{fg} (18.0)
Weed Free	0.7^{c} (0.0)	0.7^{h} (0.0)	0.7 ^{h} (0.0)	0.7^{h} (0.0)
Weedy Check	13.4^{a}(178.7)	22.7^{a}(513.7)	4.8^{a} (22.6)	20.1^{a} (404.5)
Weedy Check + Mulching	13.4^{a}(180.6)	19.3^{b}(371.4)	3.9^{bcdef} (14.8)	16.8^{b} (281.5)
LSD (0.05)	3.4	2.7	0.7	2.5
CV (%)	18.8	17.5	10.9	19.2

CV= coefficient of variation; LSD= least significant difference; WAE= weeks after crop emergence; NS= not significant; Means in column of same parameter followed by the same letter(s) are not significantly different at 5% level of significance. PEN = Pendimethalin, MET = S-metolachlor, HWH= hand weeding and hoeing, No/m^{-2} = number per metre square, g m^{-2} = gram per metre square

4.3 Weed control efficiency (WCE)

At 2 WAE, pendimethalin 1.00 kg/ha+ mulching recorded significantly higher weed control efficiency (62.4%) followed by s-metolachlor 0.75 kg/ha+ pendimethalin 0.75 kg/ha+ mulching (56.6 %) (Table 5). At 12 WAE, the highest weed control efficiency (99.8%) was obtained with hand weeding and hoeing at 2 and 5 WAE which is statistically at parity with pendimethalin 1.00 kg/ha+ Hand weeding and hoeing 5 WAE (99.4%). Singh et al. (2013) observed that integration of hand weeding with herbicide attributed to efficient and prolonged weed control.

Table 4 Effect of different weed management practices on weed control efficiency in common bean

Treatments	Weed control efficiency (%)	
	2 WAE	12 WAE
S-metolachlor 1.00 kg/ha+ Mulching	26.5[i]	83.1[g]
Pendimethalin 1.00 kg/ha+ Mulching	62.4[a]	88.8[e]
S-metolachlor 1.00 kg/ha+ Hand weeding and hoeing 5 WAE	17.7[j]	71.8[k]
Pendimethalin 1.00 kg/ha+ Hand weeding and hoeing 5 WAE	50.9[c]	99.4[a]
S-metolachlor 0.75 kg/ha+ Pendimethalin 0.75 kg/ha	44.3[e]	90.3[d]
S-metolachlor 0.75 kg/ha+ Pendimethalin 0.75 kg/ha+ Mulching	56.6[b]	97.7[b]
S-metolachlor 0.50 kg/ha+ Pendimethalin 0.75 kg/ha	34.5[g]	74.9[j]
S-metolachlor 0.50 kg/ha+ Pendimethalin 0.75 kg/ha+ Mulching	41.6[f]	81.2[h]
S-metolachlor 0.75 kg/ha+ Pendimethalin 0.50 kg/ha	47.9[d]	75.9[i]
S-metolachlor 0.75 kg/ha+ Pendimethalin 0.50 kg/ha+ Mulching	56.6[b]	86.6[f]
Hand weeding and hoeing at 2 and 5 WAE	8.4[k]	99.8[a]
Hand weeding and hoeing at 2 WAE+ Mulching	31.4[h]	95.6[c]
Weedy Check	-	-
Weedy Check+ Mulching	34.5[g]	30.4[l]
LSD (0.05)	1.2	0.8
CV (%)	2.1	0.7

CV= coefficient of variation; LSD= least significant difference; WAE= weeks after crop emergence; NS= not significant; Means in column of same parameter followed by the same letter(s) are not significantly different at 5% level of significance.

4.4 Yield components and Yield

4.4.1 Crop stand count

It was found that none of the weed management treatments resulted in significant variation in initial plant stand of common bean thus data not given. However, at harvest the crop stand count was significantly influenced by different weed management practices. The highest stand count (243523 plants/ha) was recorded in weed free. However, it was statistically at par except with s-metolachlor 0.50 kg ha^{-1}+ pendimethalin 0.75 kg ha^{-1}, s-metolachlor 0.75 kg ha^{-1} + pendimethalin 0.50 kg ha^{-1}, hand weeding 2 WAE supplemented with mulching and weedy check. Comparatively higher survival of the plants observed could be due to better competitive ability of crop plants for growth resources in the absence of weed competition.

Weedy check though recorded lowest plant stand at harvest but it did not differ significantly with s-metolachlor 0.50 kg ha^{-1}+ pendimethalin 0.75 kg ha^{-1} and weedy check supplemented with mulching. Weedy check along with mulching also resulted in significant reduction in crop stand but was found statistically similar to s-metolachlor at 1.0 kg ha^{-1} + mulching. The presence of higher weed density and weed dry weight might have lead to lower survival ofcrop plants. The high weed infestation might have resulted in severe competition for nutrients, light, space and moisture with the crop. Jakhar et al (2012) pointed that two rotary weeding at 20 and 40 DAS reduced the growth of weeds resulted in higher weed control efficiency in soybean over all other weed control treatments.

4.4.2 Number of pods per plant

The highest number of pods per plant (9.9 pods/plant) was recorded under weed free which was statistically in parity with pendimethalin at 1.0 kg ha^{-1}+ hand weeding and hoeing 5 WAE. On the other hand, the latter treatment had no significant difference with s-metolachlor 0.75 kg ha^{-1}+ pendimethalin 0.75 kg ha^{-1}+ mulching, hand weeding and hoeing at 2 and 5 WAE and hand weeding and hoeing at 2 WAE + mulching. Amongst various herbicide mixtures with and without mulching, s-metolachlor at 0.75 kg ha^{-1} + pendimethalin at 0.75 kg ha^{-1} + mulching, recorded the highest number of pods/plant (8.4) which was statistically at par with s-metolachlor at 0.50 kg ha-1 + pendimethalin at 0.75 kg ha-1 + mulching and s-metolachlor at 0.75 kg ha^{-1} + pendimethalin at 0.50 kg ha^{-1}. This showed the superiority of s-metolachlor at 0.75 kg ha^{-1} + pendimethalin at 0.75 kg ha^{-1} + mulching over s-metolachlor at 0.75 kg ha^{-1} + pendimethalin at 0.75 kg ha^{-1}, s-metolachlor at 0.50 kg ha^{-}1+ pendimethalin at 0.75 kg ha^{-1} and s-metolachlor at 0.75 kg ha^{-1} + pendimethalin at 0.50 kg ha^{-1} +mulching. This indicated that mulching had positive effect when applied with higher rates of herbicide mixtures. This might be due to effective control of weeds with mixtures which was enhanced when supplemented with mulching. Weedy check decreased significantly number of pods/plant over other treatments and this decrease varied between 28.6 and 54.4% (Table 5).

Pod number per plant is the first yield component to be determined in the reproductive phase followed by seed per pod and seed weight (Woolley *et al*., 1993). Thus, among yield components, pod number per plant is likely to be the most sensitive yield component to weed interference. Ayaz et al. (2001) stated that the number of pods produced per plant or maintained to final harvest depends on a number of environmental and management practices. Mirshekari (1999) also showed that the presences of weeds are effective factor in reducing number of pods in cowpea plant. Dadari (2003) reported that competition between weeds and crop starts right from germination of the crop up to harvest affecting both growth and yield parameters adversely. Similar results were reported by Abu Hamdeh, (2003); Chmielowiec and Borowy (2004); Tesfay and Amin (2013) in bean.

4.4.3 Number of seeds per pod

The highest number of seeds/pod (7.9 seed/pod) was obtained with complete weed free plots which was statistically in parity with pendimethalin at 1.0 kg ha^{-1} + hand weeding and hoeing 5 WAE, pendimethalin at 1.0 kg ha^{-1} + mulching, s-metolachlor 1.0 kg ha^{-1} + hand weeding and hoeing 5 WAE, s-metolachlor 0.75 kg ha^{-1}+ pendimethalin 0.75 kg ha^{-1}mulching s-metolachlor 0.50 kg ha^{-1} + pendimethalin 0.75 kg ha^{-1}and hand weeding and hoeing 2 and 5 WAE. In general, mulching helped in improving the number of seeds/pod, but it was not significant except in treatments s-metolachlor at 0.75 kg ha^{-1} + pendimethalin at 0.75 kg ha^{-1} in which mulching increased number of seeds per pod by 22.6% (Table 5). It was also observed that one hand weeding and hoeing at 2 WAE when supplemented with mulching proved statistically inferior to two hand weeding and hoeing at 2 and 5 WAE.

The untreated control gave the least number of seeds/pod and the differences with other treatments were significant (Table 9). The lowest number of seeds per pod in weedy check treatment may be due to high weed infestation during the growing period of the crop. This result agreed with the findings of Sharma *et al*. (2004) who reported that number of seeds pod^{-1} was significantly reduced with the increased weed infestation and significantly increased with the weed free period in common bean. These results are in agreement with the findings of Jafari et al. (2013) in bean, who stated that pre emergent herbicides increased the plant height, pods per plant and seed number per pod significantly as compared to weedy check.

4.4.4 Hundred grain weight

Weight of hundred seeds was maximum with complete weed free which was statistically in parity with the application of pendimethalin at 1.0 kg ha^{-1} + hand weeding and hoeing at 5 WAE and two hand weeding and hoeing 2 and 5 WAE treatments. This might be in general, due to more and vigorous leaves under reduced weed competition which improved the supply of assimilate to be stored in the grain, hence, the hundred seed weight increased. Furthermore, the higher hundred seed weight recorded from these treatments might be due to availability of more space for better light interception, resulting in better utilization of other growth resources for grain development. No significant difference was found between mulching and non mulching when plots were treated with s-metolachlor at 0.75 kg ha^{-1} + pendimethalin at 0.75 kg ha^{-1}, s-metolachlor at 0.50 kg ha^{-1} + pendimethalin at 0.75 kg ha^{-1}, and s-metolachlor at 0.75 kg ha^{-1} + pendimethalin at 0.50 kg ha^{-1} and weedy check. However, 100 seed weight was significantly lower in weedy check with and without mulching than the other treatments (Table 5). Reduced weight of 100 seeds observed at weedy check treatments which might have resulted due to high weed infestation. This result was in agreement with those of Spader and Vidal (2000) who noted decrease in grain weight of maize with an increase in weed density. Yield losses caused by weed

4.4.5 Grain yield

The highest yield (1982 kg ha^{-1}) was obtained with the application of pendimethalin at 1.0 kg ha^{-1} + hand weeding at 5 WAE which was statistically in parity with two hand weeding at 2 and 5 WAE and complete weed free. Further, hand weeding and hoeing at 2 and 5 WAE was statistically in parity with pendimethalin at 1.0 kg ha^{-1} + mulching. Suppression of weed competition was further enhanced by integrating hand weeding kept the crop weed free during critical periods of 35 DAE which offered prolonged and efficient weed control thus reducing weed crop competition (Mondal et al., 2005; Warade et al., 2006).

It was also revealed that mulching had no significant effect on grain yield over their respective non mulched treatments barring s-metolachlor at 0.75 kg ha^{-1} + pendimethalin at 0.75 kg ha^{-1} in which mulching resulted in significant increase (21%) in grain yield over no mulching. In contrast, Dawit et al. (2011) reported that pendimethalin 0.75 kg ha^{-1} supplemented with one hand weeding at 35 days after sowing resulted in 15.5 % higher yield than twice hand weeded at 20 and 35 days after sowing. Higher yield in better treatment may be due to lesser weed crop competition for growth recourses, thus providing congenial environment to the crop for better expression of growth and yield. This may presumably also be due to the concomitant supply of growth resources and translocation of photosynthates effectively to sink.

4.4.5 Aboveground dry biomass yield

The comparison of the mean values of the biomass yield showed that the highest biomass yield (4773 kg ha^{-1}) of common bean was obtained with application of pendimethalin at 1.0 kg ha^{-1} + hand weeding and hoeing 5 WAE which was statistically at par with the aboveground dry biomass yield obtained with the application of s-metolachlor at 1.0 kg ha^{-1} + hand weeding and hoeing at 5 WAE, hand weeding and hoeing at 2 and 5 WAE and weed free. On the other hand, mulching had no beneficial effect on aboveground dry biomass over their respective herbicide mixtures.

It was also revealed that application of s-metolachlor at 1.0 kg ha^{-1} when superimposed with hand weeding at 5 WAE did not show significant improvement in aboveground dry biomass over s-metolachlor at 1.0 kg ha^{-1} + mulching. In contrast, significantly higher aboveground dry biomass was registered with pendimethalin at 1.0 kg ha^{-1} + hand weeding at 5 WAE over pendimethalin at 1.0 kg ha^{-1} + mulching. Weedy check had significantly lower aboveground dry biomass than the other treatments, but it was statistically at par with weedy check + mulching only. The results was in conformity with the findings of Sadegh (2013) who reported that among the weeds control methods, the highest biomass yield was obtained at application of Bentazon + once handing weeding treatment and the lowest biomass yield was at control treatment in red bean (*Phaseolus vulgaris L.*).

Table 5 Effect of weed control treatments on yield attributes and yield of common bean

Treatment	Number of pods/plant	Number of seeds/pod	Hundred seed weight(g)	Aboveground dry biomass (kg ha^{-1})	Grain yield (kg ha^{-1})	Harvest index (%)
MET 1.00 kg^{-1} + Mulching	6.8^{de}	7.0^{abcde}	25.8^{de}	4430^{bc}	1446^{cd}	32.6^{abcde}
PEN 1.00 kg^{-1} + Mulching	7.9^{cd}	7.1^{abcde}	29.3^{bcd}	4444^{bc}	1672^{bc}	37.6^{abc}
MET 1.00 kg^{-1} + HWH 5 WAE	6.8^{de}	7.6^{abc}	25.3^{ef}	4798^{ab}	1455^{cd}	30.4^{cde}
PEN 1.00 kg^{-1} + HWH 5 WAE	9.6^{ab}	7.8^{ab}	31.1^{ab}	5013a	1982^{a}	39.5^{a}
MET 0.75 kg^{-1} + PEN 0.75 kg-1	6.6^{e}	6.2^{e}	26.8^{de}	4236^{c}	1309^{d}	30.9^{bcde}
MET0.75kg^{-1}+ PEN0.75kg^{-1} + Mulching	8.4^{bc}	7.6^{abc}	28.1^{bcde}	4321^{c}	1584^{c}	36.7^{abc}
MET 0.50 kg^{-1} + PEN 0.75 kg^{-1}	6.5^{e}	7.3^{abcd}	26.4^{de}	4195^{c}	1466^{cd}	35.0^{abcd}
MET 0.5kg^{-1}+ PEN0.75 kg^{-1} + Mulching	7.7^{cde}	7.0^{abcde}	29.2^{bcd}	4225^{c}	1583^{c}	37.5^{abc}
MET 0.75 kg-1 + PEN 0.50 kg-1	7.9^{cd}	6.4^{de}	28.4^{bcde}	4279^{c}	1530^{cd}	35.8^{abcd}
MET 0.75kg^{-1}+ PEN 0.50kg^{-1}+ Mulching	6.3^{e}	6.9^{bcde}	28.3^{bcde}	4397^{bc}	1606^{c}	36.5^{abc}
HWH at 2 and 5 WAE	8.5^{bc}	7.7^{abc}	30.9^{abc}	5008^{a}	1885^{ab}	37.6^{abc}
HWH at 2 WAE + Mulching	8.4^{bc}	6.8^{cde}	27.3^{cde}	4452^{bc}	1566^{c}	35.2^{abcd}
Weed Free	9.9^{a}	7.9^{a}	33.1^{a}	5016^{a}	1920^{a}	38.3^{ab}
Weedy Check	4.9^{f}	4.7^{f}	20.5^{g}	3442^{d}	937^{e}	27.2^{e}
Weedy Check + Mulching	4.5^{f}	4.9^{f}	22.2^{fg}	3453^{d}	1012^{e}	29.3^{de}
LSD (0.05)	1.2	0.8	3.2	423.1	223.3	6.3
CV (%)	9.6	7.1	7.0	5.8	8.7	10.8

4.5 Economic return

The economic analysis revealed that highest net returns of 17362 and 17120 Birr ha^{-1} were obtained by application pendimethalin 1.0 kg ha^{-1} + hand weeding and hoeing 5 WAE and hand weeding and hoeing 2 and 5 WAE which was 95.1 and 93.2% higher, respectively, over weedy check (Table 6). Effective and economic weed control is essential as weeds are the most efficient users of resources due to their different kinds, intensity and fast growth habits. Even though there was high costs that varied, there is higher yields in the pendimethalin 1.0 kg ha^{-1} + hand weeding and hoeing at 5 WAE treatment which resulted in higher net returns than the other weed control methods. Thus, the application of pendimethalin 1.0 kg ha^{-1} + hand weeding and hoeing 5 WAE weed control method was the most profitable weed control methods than others. In line with this result, Meena et al. (2009) reported maximum net returns and highest cost: benefit in pre-emergence application of oxadiargyl at 75 g ha^{-1} + hand weeding at 45 DAS followed by pre-emergence application of pendimethalin at 1.0 kg ha^{-1} + hand weeding at 45 DAS over rest of the treatments in cumin (*Cuminum cyminum* L.).

Table 6 Economic return of different weed management practices in common bean

Treatments	Grain yield	Adjusted yield	Gross benefit	Total cost that varied	Net return	B:C ratio
	(kg ha^{-1})	(kg ha^{-1})	(Birr ha^{-1})	(Birr ha^{-1})	(Birr ha^{-1})	
S-metolachlor (MET) 1.00 kg/ha + Mulching	1446.3	1301.3	13617	2697	10920	4.05
Pendimethalin (PEND)1.00 kg/ha + Mulching	1671.5	1504.4	18053	3876	14177	3.66
MET 1.00 kg/ha+Hand weeding and hoeing 5 WAE	1455.2	1309.6	15715	2533	13182	5.20
PEND1.00kg/ha+Hand weeding and hoeing 5 WAE	1981.9	1783.7	21404	4042	17362	4.30
MET 0.75 kg/ha+ PEND 0.75 kg/ha	1309.5	1178.5	14142	2911	11231	3.86
MET 0.75 kg/ha+ PEND 0.75 kg/ha+ Mulching	1583.9	1425.5	17106	3762	13344	3.55
MET 0.50 kg/ha+ PEND 0.75 kg/ha	1466.3	1319.7	15836	2976	12860	4.32
MET 0.50 kg/ha+ PEND 0.75 kg/ha+ Mulching	1583.0	1424.7	17096	3654	13442	3.68
MET 0.75 kg/ha+ PEND 0.50 kg/ha	1529.6	1376.6	16519	2812	13707	4.87
MET 0.75 kg/ha+ PEND 0.50 kg/ha+ Mulching	1606.2	1445.6	17347	3436	13911	4.05
Hand weeding and hoeing at 2 and 5 WAE	1885.1	1696.6	20359	3239	17120	5.29
Hand weeding and hoeing at 2 WAE + Mulching	1565.9	1409.3	16911	3145	13766	4.38
Weedy Check	937.2	843.5	10122	1027	9095	8.86
Weedy Check + Mulching	1012.1	910.9	10930	2068	8862	4.29

WAE = weeks after crop emergence; Cost of s-metolachlor 429 Birr kg^{-1}; cost of pendimethalin 1360 Birr kg^{-1}; Spraying Birr 135 ha^{-1}; Cost of first hand weeding and hoeing 32 persons @Birr 25 ha^{-1}; second hand weeding 15 person @ Birr 25 ha^{-1}; Cost of mulch and application Birr 550 ha^{-1}; Sale price of common bean Birr 12 kg^{-1}; Field price of common bean (sale price- cost of harvesting, threshing and winnowing Birr 105 per 100 kg; packing and material cost Birr 6.70 per 100 kg, transportation Birr 10 per 100 kg.

5. CONCLUSIONS AND RECOMENDARTION

The common bean field was infested with nine weed species which belonged to five families. The total weed density though was lowest due to the application of pendimethalin 1.0 kg ha^{-1}+ mulching it had no significant difference except with s-metolachlor 1.0 kg ha-1 + mulching, combination of s-metolachlor + pendimethalin (0.75 + 0.75 kg ha^{-1}), (0.75 + 0.50 kg ha^{-1}), (0.50 + 0.75 kg ha^{-1}) and weedy check with and without mulching. At 2 WAE, the lowest weed dry weight was found in pendimethalin 1.0 kg ha^{-1} + hand weeding and hoeing 5 WAE, but it was statistically in parity with other treatments except with s-metolachlor 1.0 kg ha^{-1} + mulching, s-metolachlor 1.0 kg ha^{-1} + hand weeding and hoeing 5WAE, s-metolachlor 0.50 kg ha^{-1} + pendimethalin 0.75 kg ha^{-1} with and without mulching, hand weeding and hoeing at 2 and 5 WAE and hand weeding with mulching. On the other hand, at 12 WAE, the minimum weed dry weight was registered in plots receiving two hand weeding 2 and 5 WAE which had no significant difference with weed dry weight obtained with the application of pendimethalin 1.0 kg ha^{-1} + hand weeding and hoeing 5 WAE and s-metolachlor 0.75 kg ha^{-1} + pendimethalin 0.75 kg ha^{-1} + mulching. Hand weeding and hoeing at 2 and 5 WAE gave highest weed control efficiency (99.8%) which is statistically at parity with pendimethalin 1.00 kg/ha+ hand weeding and hoeing 5 WAE (99.4%). Yield attributes were significantly influenced with the application of different weed control treatments. Results revealed that the highest yield attributes like number of pods/ plant (9.9), number of seed per pod (7.9), aboveground dry biomass (5016 kg ha^{-1}). Harvest index (39.5%) was recorded under weed free plot which was which was statistically in parity with pendimethalin at 1.0 kg ha^{-1}+ hand weeding and hoeing 5 WAE. The highest yield (1982 kg ha^{-1}) was obtained with the application of pendimethalin at 1.0 kg ha^{-1}+ hand weeding at 5 WAE which was statistically in parity with two hand weeding at 2 and 5 WAE and complete weed free. The economic analysis revealed that highest net benefit of 17362 and 17120 Birr ha^{-1} were obtained by application of pendimethalin 1.0 kg ha^{-1}+ hand weeding and hoeing 5 WAE and hand weeding and hoeing 2 and 5 WAE which was 95.1 and 93.2% higher, respectively, over weedy check. The weed check treatment incurred loss in common bean.

Generally, from results of the experiment, it could be concluded that pendimethalin 1.0 kg ha^{-1} combined with one hand weeding and hoeing at 5 WAE was the most appropriate method for effective weed management and profitable production of common bean in Woliata Sodo. Moreover, in the case of available of labour, hand weeding and hoeing 2 and 5 WAE can be considered as an alternative to increase the production of and economic benefit of common bean. In this experiment, mulching and herbicidal mixtures did not prove much beneficial in suppressing weed infestation. Therefore, there is a need to evaluate more combinations of herbicides to for broad spectrum weed control and to identify the amount and type of mulching materials. However, these results are only indicative and require further experimentation for confirmation before making final recommendation to the farmers.

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